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THE DISINTEGRATION OF BUILDING STONES IN EGYPT.

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THE DISINTEGRATION OF BUILDING STONES IN EGYPT.

In examining the nature of the decay of building stones as seen in Egypt, two points in connection with it force themselves upon the attention, namely—

1. That the action is frequently limited to a metre or a metre and a half above the ground level, or, if not actually limited to that extent, it is usually greatest at or near the surface of the ground.

2. That the decay is very often accompanied by more or less of a white incrustation or efflorescence.

This presence of an efflorescence of salts when a stone decays frequently gives rise to the idea that the efflorescence itself is not only the cause of the decay, but, as the salts forming the efflorescence are chemical bodies and the decay a corrosion, it is imagined that the disintegration is a chemical corrosion of the stone by the salts. Since, however, common salt, sodium chloride, is generally the chief and sometimes the only constituent of an efflorescence, and the stone effected is sometimes sandstone, this would mean, if it were true, that common salt exerts a chemically corrosive action upon sandstone. Such an explanation being far from probable some other solution of the difficulty must be looked for.

Since building stones are simply pieces of rock detached from the main mass in the quarry and placed together in other positions, any enquiry into the causes of the disintegration of the individual stones forming part of a building must manifestly commence with the consideration of the destructive agencies that are known to attack the stone as it occurs in nature. The natural processes concerned in the decay, or weathering as it is termed, of rocks may be divided into two kinds, namely—

1. Physical.
2. Chemical.

Of the physical causes of rock disintegration the chief are:—

(*a*) Changes of temperature.
(*b*) Frost.
(*c*) The mechanical action of water.
(*d*) Saturation and dessication.

Among the chemical agents of decay the principal are:—

(*e*) The oxygen of the air and corrosive bodies frequently found with it.
(*f*) Water and various substances that may be contained in it.

(*a*) *Changes of temperature.*—Variation of temperature, more particularly the very marked variation that occurs in Egypt between day and night, which even at Cairo amounts to 28° C. in May and June, is an important factor in rock disintegration. During the day the surface of the rock becoming strongly heated expands considerably, while at night it cools and contracts again. Thus a perpetual strain is kept up which eventually causes the outer surfaces to crack and peel off.

(*b*) *Frost.*—This is a most powerful agent in the destruction of rocks. The moisture contained in the pores and crevices freezes and expands and thus splits up the rock; but this rarely occurs in Egypt, except at considerable altitudes in the Eastern Desert.

(*c*) *The mechanical action of water.*—Water acts mechanically in two ways, first by direct abrasion or erosion, and secondly by penetrating the rock-mass and destroying the cohesion existing among the component particles.

(*d*) *Saturation and dessication.*—Alternate wetting and drying also loosens and separates the various particles of a rock, thus rendering it more susceptible to any further disintegrating influences to which it may afterwards be subjected.

(*e*) *Atmospheric influences.*—The oxygen of the air and any acid bodies that may be present with it are very active agents in rock disintegration, and have a direct action upon the stone, modifying and transforming it in such a manner that it readily crumbles away.

(*f*) *The chemical action of water.*—Strictly speaking there is no water quite pure and no rock absolutely insoluble, and when the action is continued for thousands of years and the active agent constantly renewed, water that is ordinarily considered pure in reality exerts a powerful solvent action even on the hardest rocks, and a still greater solvent action takes place when the water contains in solution, as it frequently does, various corrosive bodies, such as carbon dioxide, organic acids, ammonia, or alkaline carbonates.

In the case under consideration, however, namely, the rapid decay of building stones at or near the ground level, accompanied by an efflorescence, most of the agencies just enumerated may be neglected, for, although not without effect, they cannot be the principal causes of the disintegration.

The effects of changes of temperature may be omitted because such changes are felt over the whole surface and are not limited to the base of a building. The action of frost, too, need not be taken into account, since in the Nile Valley it is very rare.

The direct mechanical abrasion or erosion by water may also be discarded, for this only occurs when large volumes of moving water act throughout a long period.

The effects of corrosive bodies in the atmosphere or in rain-water can also be put on one side, these too would have no selective action upon the stones at the bottom of a building; further, in Egypt such bodies are present only in minute quantites and would require a considerable number of years to produce the results that are known to be caused quickly.

One is thrown back therefore upon the efflorescence and the relation it must have to the decayed stone. Can it be indeed the cause of the mischief, or is it simply an incidental accompaniment of it? And if it be the cause, in what manner does it operate?

In an endeavour to find the answers to these questions the following series of experiments were made. At the commencement of the experiments it was assumed that the cause sought for could only operate in the presence of moisture. To put together a dry salt and a dry stone and to expect any reaction whatever seemed a waste of time, and hence water was present at some period or other during the course of all the experiments.

Experiment No. 1.—Five small cubes of various Limestones used for building, though none of very good quality, were taken and were placed each upon a layer of sand at the bottom of a shallow dish.

In two cases the sand was moistened from time to time with distilled water, in one case with a 10% solution of sodium chloride, in another case with a 10% solution of sodium nitrate, and in the remaining case with a 10% solution of sodium carbonate. In each instance the stones were allowed to become alternately wet and dry, wet by absorption of the water from the sand, and dry in the intervals between the several waterings. The experiment lasted five months, the stones being observed daily and their condition recorded.

The results briefly summarized were as follows:—

No. 1 and 2.—Treated with distilled water. There was a slight efflorescence of salts at the top giving the stones a blistered appearance, and in places, especially at the top corners, a thin layer of the stone had become partly detached from the surface by a growth of crystals underneath. After spraying with water to remove the efflorescence the stones were left with a corroded and pitted surface.

No. 3.—Treated with sodium chloride. In this case, although there was fair amount of efflorescence, there was no visible corrosion and no marked separation of a surface layer by the salt crystals. On washing off the efflorescence, however, the surface was found to be slightly pitted.

No. 4.—Treated with sodium nitrate. There was a fair amount of efflorescence and the stone was blistered in places, and was found to be slightly corroded when the efflorescence was removed.

No. 5.—Treated with sodium carbonate. In this case a considerable efflorescence quickly formed, and in places a thin layer of stone very soon became partly separated from the surface of the cube by a growth of crystals underneath. These crystals, which varied in length from five to ten millimetres, were needle-shaped and projected from the stone as though held by the point. The action daily increased, and a stencilled number which had originally been on the face of the cube was soon standing out at a distance of seven millimetres, and was entirely separated from the stone by the crystalline growth. That is to say, the surface layer of stone which had the number of the cube stencilled on it had been undermined, it had become separated and pushed out until it was seven millimetres away, and had quite ceased to be in contact with the stone at any point, being merely held in position by the crystals.

After a time a small corner piece of the stone, not simply a surface layer, was pushed bodily off by a growth of crystals underneath. It seems probable, although no fracture was visible, that the stone had been previously cracked at this point, and that the crystals forming in the crack had gradually widened it until the piece fell off.

After about a month the dense crystalline growth fell away from the sides of the cube, leaving the surface quite bare and free from efflorescence. On adding water the crystals which had fallen dissolved, and the outer layer of the stone with the stencilled number still on it lay exposed at the bottom of the basin. When the crystals dissolved the solution which was formed was of a dark brown colour, and it had been previously noted that the efflorescence, although at first white, became after a time quite brown in places, more particularly at the top and top corners of the cube.

The efflorescence never fully formed again in those places from which the previous crystals had fallen.

At the end of five months the cube was washed and examined, and it was found that distinct depressions existed at the sides, showing clearly where the surface had been forced away.

The following table gives the results of the experiments:—

TABLE I.

No. of Cube.	NAME OF QUARRY	Soluble matter in stone.	Soluble matter in sand.	Duration of experiment.	Solution used to moisten sand.	RESULT.
		%	%			
43	Doweiqa* . ..	0 62	0·07	5 months.	Distilled water.	Much corrosion and pitting.
44	Gebel El Abyad*	0·19	0·07	„	Distilled water.	Much corrosion and pitting.
41	Batn-el-Baqara †	0·30	0·24	„	Sodium chloride.	Slight corrosion end pitting.
45	Zawiet Nasra* ..	0·36	0·24	„	Sodium nitrate.	Slight corrosion and pitting.
47	Batn-el-Baqara †	0·39	0 24	„	Sodium carbonate.	Very marked disintegration.

EXPERIMENT No. 2.—During a period of three months another and similar experiment was made.

In those cases in which distilled water only was used the stones were dense and not very porous, and at the end of three months the water had not been able to mount to the top of the cube.

At the level that the water reached, which was about half-way up, there was a slight efflorescence, but not the slightest sign of corrosion.

Where sodium sulphate was used the stone also was not very porous and a dense growth of crystals formed about half-way up the sides where the water had penetrated. After washing off the efflorescence no signs of disintegration were visible.

In one case calcium sulphate was used with a fairly porous stone. In this instance there was a slight efflorescence at the top of the cube and a very slight disintegration at the top corners.

Sodium carbonate was also used again, and in this case too the stone was a fairly porous one. A very marked iron discoloration was soon visible at the top of the cube and gradually increased until the top edges and corners were of a dark brown colour.

A thin surface layer of the stone quickly became detached in places and fell away. This disintegration went on throughout the duration

* West face of Gebel Moqattam. † East of "Old Cairo."

of the experiment, and at the end of the three months the stone was much corroded.

The following table shows the results of the experiment:—

TABLE II.

No. of Cube.	NAME OF QUARRY.	Soluble matter in sand.	Duration of experiment.	Solution used to moisten Sand.	RESULT.
		%			
13	El Basatin *	0·24	3 months.	Distilled water.	Nil.
17	El Tablita *	0·24	,,	Distilled water.	Nil.
16	El Amara.	0·24	,,	Calcium sulphate.	Very slight corrosion.
21	Atar-el-Nebi	0·24	,,	Sodium carbonate.	Marked disintegration.
30	Atar-el-Nebi	0·24	,,	Sodium sulphate.	Nil.

EXPERIMENT No. 3.—Concurrently with experiment No. 2, another experiment was conducted on somewhat different lines. In this case the cubes of stone were placed in deep glass vessels and were entirely covered by the various solutions, water being added from time to time to make up for that lost by evaporation. After three months the stones which had been in distilled water, sodium chloride solution, sodium nitrate solution and calcium sulphate solution showed absolutely no change of any sort. With sodium sulphate there was an exceedingly slight iron discoloration in the solution, while in the case of sodium carbonate this iron discoloration, which was evident after a few days, became finally very marked.

The following table gives the final results of the experiment:—

TABLE III.

No. of Cube.	NAME OF QUARRY.	Duration of experiment.	Solution used.	RESULT.
19	Ain-el-Sira	3 months.	Distilled water.	Nil.
19	,,	,,	Sodium sulphate.	Merest trace of iron discoloration in solution.
19	,,	,,	Sodium nitrate.	Nil.
19	,,	,,	Sodium carbonate.	No visible corrosion. Iron discoloration in solution.
7	Helwan	,,	Sodium chloride.	Nil.
7	,,	,,	Calcium sulphate.	Nil.

In addition to the experiments enumerated above a large number of buildings in which the stones showed signs of disintegration were examined. In every case the amount of soluble salts iu the disintegrated stones was large, and in some instances very considerable. Occasionally, in the case of walls that had been plastered, the plaster was forced bodily away from the wall, and in between the wall and the plaster a sheet of almost pure sodium chloride, sometimes one or even two millimetres in thickness, was found. In other cases small cavities in the mortar, or in the stone, or in the space between the plaster and the stone, were filled with a powdery mass of crystals of almost pure sodium chloride. In fact, sodium chloride was the chief constituent of all the efflorescences examined, though sometimes nitrates and sulphates were also present.

Although the disintegration was always greatest at or near the ground level, yet sometimes one or more individual stones in the middle of a wall otherwise good would be badly decayed, and on examination a large proportion of soluble salts was invariably found, even though no distinct efflorescence was visible.

The stones attacked were frequently in such a condition of decay that on being merely touched large portions of the surface simply crumbled to powder.

The inevitable conclusion forced upon one from both observation and experiment is that in addition to the disintegration caused by changes of temperature by the oxidizing action of the atmosphere, or by the corrosive action of acid bodies either in the air or in the rain, there is also in Egypt a considerable disintegration of building stones, most frequently, though not always, near the ground level, and that this disintegration is conditioned by:—

1. The presence of moisture.
2. The degree of porosity of the stone.
3. The presence either in the stone or in the ground of salts readily soluble in water.
4. Opportunity for the salts to crystallize out by the evaporation of the water holding them in solution.

This special disintegration is in all cases largely physical, and in most cases wholly so, and the essential conditions for its action are the presence of water, with or without soluble salts, and a porous stone.

In the case of stones decaying near the ground level the water is invariably derived from the soil, which is always in a more or less saturated state. During the time that the Nile is in flood this saturation is caused by the infiltration water from the river, while in the spring

and early summer when the Nile is low a similar state of things is brought about by the copious way in which the gardens and paths round a building are watered.

In the case of the decay of stones not near the ground, the moisture comes partly from that with which the stones are drenched at the time they are laid, partly from the wet mortar, and partly from the absorption and retention of any rain or morning mist that may reach them.

The mere penetration of the mass of the stone by water tends to destroy the cohesion existing among the component particles, and if, as is usually the case, the stones become alternately wet and dry then this disintegrating action is much increased. Disintegration is enormously aggravated by the presence of soluble salts such as sodium chloride, sodium sulphate, sodium carbonate, etc. A certain amount of some at least of these salts is usually present in all the ordinary building stones used in Egypt. This may readily be seen from the following tables in which the results of the examination of 95 different specimens of Limestones are given :—

TABLE IV.

NATURE OF STONE.	Number of samples examined.	TOTAL MATTER SOLUBLE IN WATER.		
		Highest.	Lowest.	Mean.
		%	%	%
Limestone	95	3·35	0·12	0·71

TABLE V.

	PERCENTAGE OF MATTER SOLUBLE IN WATER.											Total number of samples examined.
	Under 0·25	Over 0·25 Under 0·50	Over 0·50 Under 0·75	Over 0·75 Under 1·00	Over 1·00 Under 1·25	Over 1·25 Under 1·50	Over 1·50 Under 1·75	Over 1·75 Under 2·00	Over 2·00 Under 2·50	Over 2·50 Under 3·00	Over 3·00	
Number of Samples.	12	38	24	5	2	1	4	3	3	1	2	95

The chief source of soluble salts, however, is the soil which contains large amounts of chlorides, sulphates, nitrates, etc.

This is clearly shown by the following table, which gives the amounts of soluble matter found in some samples of soil taken from various parts of Cairo and neighbourhood:—

TABLE VI.

No. of sample.	LOCALITY FROM WHICH TAKEN.	Depth at which taken.	Matter soluble in water.*
		Cent.	%
61	Garden of P. W. D. Offices, near west wall of enclosure	0 to 10	7·23
62	„ „ „ east entrance	0 to 10	8·29
63	„ „ „ north entrance..	0 to 10	2·03
64	„ „ „ north wall of enclosure	0 to 10	20·26
65	Site of new fire station, north side..	0 to 10	4·19
66	„ „ south-west side.	0 to 10	3·32
67	Site of new house, Chareh Insha, Saida Zenab	0 to 10	3·07
68	„ „ „ „	230	0·69
69	„ „ near Saida Zenab station.	0 to 10	0·59
70	„ „ „ „	160	0·57
72	„ „ at Ghezireh.	0 to 10	0·47
73	„ „ „	180	0·16
77	Abassia. Native village, near Observatory..	0 to 10	0·62
78	Site of new house at Abassia, near Observatory..	0 to 10	0·89
79	„ „ „ „	500	1·13
80	„ „ near Manchiet el Sadr station	0 to 10	1·74
81	„ „ „ „ „	100	0·36
82	Helwan. Waste ground near Tewfik Palace Hotel	0 to 10	5·67
83	„ „ east of station..	0 to 10	4·60
84	Helwan. Site of new house near Grand Hotel	0 to 10	16·41
85	„ „ „ „	100	1·13
86	Cairo. Near Bab el Luq station	0 to 10	4·52
87	„ Chareh Dawaween.	0 to 10	5·23
88	„ „ Sheik Rehan	0 to 10	9·52
89	„ Site of new house, Chareh Abdeen	0 to 10	5·19
90	„ „ „ „	270	1·08

Mean of 26 samples 4·19%.

These salts are drawn up from the ground and into the stone by capillary attraction, the water in which they are dissolved evaporates at the surface of the stone and the salts crystallize out, and by the sheer

* In all cases this has been calculated on the soil dried at 100° C.

force of the growth of the crystals, cause the outer layers of the stone to scale off.

Where alkaline carbonates are present there would seem to be in addition to the disintegration caused physically by the mere crystallization of the salts, also a certain amount of chemical action in which the iron compounds in the stone are more especially liable to attack.

Since the cause of the disintegration is the entry into the stone of moisture and soluble salts, chiefly from the ground, with the subsequent evaporation of the water and the crystallization of the salts, the remedy obviously is to prevent any water from gaining access, and the soluble salts, since they cannot penetrate in the dry state, are kept out at the same time.

Moisture may be prevented from rising in two ways:—

1. By an efficient damp proof course.
2. By the use of dense non-porous stone.

1. *Damp proof course.*—This is the ordinary means adopted to prevent the damp from rising, and consists in interposing a layer of some impervious material throughout the entire thickness of a wall above the ground level. The materials in general use for this purpose are asphalt, cement, and slate, though other substances, such as sheet lead and vitrified brick, are sometimes used.

2. *Good quality stone.*—For such constructions as bridges, regulators, etc., where it is impossible to use a damp proof course on account of the fluctuation of the water level, the use of a good quality stone is essential. This being non-porous does not absorb the water or soluble salts, and so is in itself a very efficient damp proof course.

A non-absorbent stone is also an excellent precautionary measure in addition to a damp proof course for the first metre or metre and a half above the ground level of all buildings of importance, as also for those parts of a building on which the water is most liable to lodge, such as copings, mouldings, window sills, etc., when these are not protected by plaster.

A dense stone possesses the further advantage of being not only non-absorbent, but is as a rule free from anything more than traces of soluble salts, and has generally in addition a high crushing strength.

The best stone in the neighbourhood of Cairo is that from the Atar-el-Nebi quarries. The other good quality stones in the order of excellence as given in the "Preliminary Report on the Quarries round Cairo" are Bassatin (top bed) El Rifai, El Tablita, Bassatin (other than top bed) El Amara, El Motabbak and Deir-el-Tin.

The remaining quarries, of which there are about twelve, yield stone of only second rate quality. This, however, is quite good enough for ordinary purposes, such as walls and buildings of no great importance, and for the upper portions of most buildings, since the plaster with which it is customary to cover the stone forms an excellent protective coating.

In the following table will be found details of the chemical examination of 95 specimens of Cairo building stone. These samples were all collected by T. Barron, F.G.S., for the report on the Quarries of Egypt. The analyses make no pretence to absolute scientific accuracy. Any such detailed work would have demanded an amount of time altogether disproportionate to the immediate object to be served. The main constituents only were determined, those of minor importance such as Titanium, Phosphorus, Manganese, Sodium, Potassium, etc., being ignored.

Table VII.

Number of Sample.	Name of Quarry.	Number of Quarry and Position of Bed.	Percentage Composition.								Matter soluble in Water.	Notes.
			Silica and Insoluble.	Iron and Aluminium Oxides.	Calcium Carbonate.	Calcium Sulphate.	Magnesium Carbonate.	Sodium Chloride.	Moisture and Organic Matter.	Total.		
											%	
115	Masara	Warsha 269 R. Bottom bed	1·10	0·56	96·90	..	2·30	..	trace	100·86	0·52	
116	, ...	,, 269 R. Top bed	1·70	0·20	98·53	..	trace	..	trace	100·43	0·12	
117	.. ..	,, 286 R.	20·02	1·38	72·30	..	4·72	..	1·68	100·10	0·58	
118	. .. .	,, 340	4·14	0·62	90·00	..	3·99	..	0·21	98·96	0·54	
119	. .. .	. 275 R. Top bed	5·34	0·58	92·00	..	2·47	..	trace	100·39	0·35	
120	. .. .	,, 275 R. Bottom bed	2·32	0·32	94·93	..	2·61	..	trace	100·18	0·20	
121	,, ...	, 282 Top bed	7·36	0·48	88·28	..	3·17	..	0·14	99·43	0·34	
122	.. ..	,, 282 Bottom bed	4·76	0·24	91·89	..	3·66	..	trace	100 55	0·26	
123	, ...	,, 480 Top bed	1·20	0·32	97·01	..	2 07	..	trace	100·60	0·20	
124	,, ...	, 480 Bottom bed	6·52	0·54	90·86	..	2·61	..	0·21	100·74	0·22	
134	Gebel Hashmi ..	.. 243 R. Top bed	66·54	1·64	20·18	..	12·54	..	0·04	100·94	0·30	
135	,, ..	,, 243 R. Middle bed	43·50	3·86	32·25	..	19·89	..	1·13	100·63	0·45	
136	,, ..	,, 243 R. Bottom bed	71·94	1·56	16·57	..	9·90	..	trace	99·97	0·17	
137	Gebel-el-Sadd ..	,, 269 3rd bed	2·18	1·44	95·24	..	trace	..	0·40	99·26	0·37	
138	Gebel Hashmi ..	,, 236 Top bed	62·42	1·76	22·32	..	13·56	..	0·55	100·61	0·34	
139	,, ..	,, 236 Middle bed	69·33	1·74	17·96	..	11·39	..	trace	100·42	0·30	
140	,, ..	,, 236 Bottom bed	48·50	4·16	28·75	..	18 14	..	1·02	100·57	0·37	
141	Gebel Messan ..	,, 238 R.	60·92	2·16	23·57	..	13·79	..	trace	100·44	0·24	
142	El Rifai	..... Middle bed	1·76	0·70	96·07	..	trace	..	0·42	98·95	0·40	
143	.. ..	..... Bottom bed	3·86	1·44	89·14	2·45	trace	..	2·20	99·09	2·45	The soluble matter is largely calcium sulphate.
[illegible]	[illegible]	[illegible] bed [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

146	Bassatin	Warsha	566	Top bed	0·74	0·50	95·48	1·97	trace	..	2·06	100·75	2·61	The soluble matter is largely calcium sulphate.
147	„	„	566	Bottom bed	1·14	0·60	97·64	..	trace	..	0·45	99·83	0·61	
151	Atar-el-Nebi	„	233³	Top bed	3·18	0·58	92·92	2·11	trace	..	1·41	100·20	2·44	The soluble matter is largely calcium sulphate.
152	„	„	233³	2nd bed	8·86	1·70	80·75	..	7·80	..	0·79	99·90	0·60	
153	„	„	233³	3rd bed	2·70	0·54	96·71	..	trace	..	trace	99·95	0·32	
154	„	„	233³	Bottom bed	1·82	0·40	98·07	..	trace	..	trace	100·29	0·47	
155	„	„	223³	Bottom bed	2·26	0·52	97·57	..	trace	..	trace	100·35	0·58	
156	„	„	232 R.	Top bed	7·26	1·72	85·61	..	trace	2·53	1·66	98·78	3·35	The soluble matter is largely sodium chloride.
157	„	„	232 R.	Bottom bed	2·98	0·82	94·64	..	trace	..	1·28	99·72	1·12	
158	„	„	445	.. ..	5·26	1·06	93·32	..	trace	..	trace	99·64	0·41	
159	„	„	222³	Top bed	4·78	0·88	91·78	..	trace	..	1·41	98·85	0·23	
160	„	„	222³	Middle bed	3·86	1·12	94·28	..	trace	..	0·59	99·85	0·28	
161	„	„	222³	Bottom bed	1·62	0·58	97·07	..	trace	..	0·12	99·39	0·14	
162	Gebel Mottabak ..	„	229	.. ..	4·36	1·34	92·57	..	trace	..	1·11	99·38	0·19	
163	Gebel Tablita ..	„	249	.. ..	2·70	1·02	93·57	..	trace	..	1·59	98·88	0·42	
164	Batn-el-Baqara ..	„	190	Top bed	2·38	1·18	96·18	..	trace	..	0·64	100·38	0 98	The soluble matter is largely sodium chloride.
165	„ ..	„	190	Middle bed	2·64	1·14	93·15	..	trace	..	1·84	98·77	0·67	The soluble matter is largely sodium chloride.
166	„ ..	„	190	Bottom bed	4·30	1·54	91·68	..	trace	..	1·66	99·18	0·72	The soluble matter is largely sodium chloride.
167	„ ..	„	186	Top bed	3·04	1·10	92·93	..	trace	..	1·77	98·84	0·81	The soluble matter is largely sodium chloride.
168	„ ..	„	186	Middle bed	9·02	2·40	81·72	1·40	trace	..	3·31	97·85	1·50	The soluble matter is largely calcium sulphate.
169	„ ..	„	186	Bottom bed	4·00	0·96	92·18	..	trace	..	1·14	98·28	0·72	
170	Abu Saud	„	173	.. ..	0·96	0·34	97·64	..	trace	..	trace	98·94	0·43	
171	Batn-el-Baqara ..	„	440	Top bed	2·62	1·02	94·39	..	trace	..	1·54	99·57	0·40	
172	..	„	440	Middle bed	2·42	0·90	95·82	..	trace	..	0·58	99·72	0·59	
173	„ ..	„	440	Bottom bed	3·78	1·28	93·33	..	trace	..	1 21	99·60	0·60	
174	Ain-el-Sira	„	146	Top bed	3·14	0·94	94·57	..	trace	..	0·70	99·35	0·70	

TABLE VII (*continued*).

Number of Sample.	NAME OF QUARRY.	NUMBER OF QUARRY AND POSITION OF BED.	PERCENTAGE COMPOSITION.								Matter Soluble in Water.	NOTES.
			Silica and Insoluble.	Iron and Aluminium Oxides.	Calcium Carbonade.	Calcium Sulphate.	Magnesium Carbonate.	Sodium Chloride.	Moisture and Organic Matter.	Total.		
											%	
175	Ain-el-Sira	Warsha 146 2nd bed	4·67	1·28	93·56	..	trace	..	1·38	100·89	0·36	
176	„	„ 146 Bottom bed	5·76	1·52	90·50	..	trace	..	1·42	99·20	0·28	
177	„	„ 150 Top bed	3·42	1·00	93·00	..	trace	..	1·11	98·53	0·32	
178	„	„ 150 Bottom bed	7·26	1·80	86·18	..	trace	..	2·12	97·36	0·59	
179	Batn-el-Baqara ..	„ 186 R. Top bed	4·30	1·20	90·61	..	trace	..	2·77	98·88	1·90	The soluble matter is largely sodium chloride.
180	„ ..	„ 186 R. Bottom bed	4·46	1·38	92·00	..	trace	..	1·80	99·64	0·92	
181	„ ..	„ 185 Top bed	8·78	2·76	84·39	..	trace	..	3·54	99·47	1·89	The soluble matter is largely sodium chloride.
182	„ ..	„ 185 Bottom bed	2·46	1·06	93·61	..	trace	..	1·85	98·98	0·63	
183	Ain-el-Sira	„ 156 Top bed	3·00	1·02	93·93	..	trace	..	1·50	99·45	0·48	
184	„	„ 156 2nd bed	3·38	0·96	93·75	..	trace	..	1·20	99·29	0·25	
185	„	„ 156 3rd bed	2·50	1·32	94·72	..	trace	..	0·70	99·24	0·39	
186	„	„ 156 4th bed	4·20	1·36	92·00	..	1·75	..	0·54	99·85	0·47	
187	„	„ 152	7·88	1·42	88·07	..	trace	..	2·02	99 39	0·59	
220	Gebel Roh	„ 502	1·80	3·24	53·64	8·04	30·07	..	3·91	100·70	3·15	The soluble matter is largely calcium sulphate.
221	Gebel Harif	„ — Top bed	5·42	2·92	72·57	..	19·21	..	trace	100·12	0·69	
222	„	„ — Middle bed	6·88	2·80	72·03	..	17·85	..	0·84	100·40	0·24	
223	Ain Musa	„ 138 Top bed	4·52	1·24	87·71	4·57	trace	..	2·02	100·06	2·34	The soluble matter is largely calcium sulphate.
224	„	„ 138 Middle bed	6·04	1·74	80·71	1·69	9·74	..	0·37	100·29	1·66	The soluble matter is largely calcium sulphate.
225	„	„ 138 Bottom bed	6·10	1·72	83·43	..	8·80	..	0·27	100·32	0·37	
233	Gebel-el-Moasala ..	„ 113 R. Top bed	2·60	0·80	94·43	..	1·44	..	0·70	99·97	0·51	
234	—	113 R. Bottom bed	1·42	0·30	96·28	..	trace	..	0·42	99·07	0·57	

236	„ ..	„	112 R.	Bottom bed	4·18	1·48	91·61	..	trace	..	1·67	98·94	0·75	
237	Gebel-el-Amara ..	„	116	Top bed	4·38	1·16	92·86	..	trace	..	1·37	99·77	0·56	
238	„ ..	„	116	Bottom bed	6·20	1·56	89·43	..	trace	..	2·08	99·27	0·37	
239	„ ..	„	110	Top bed	3·55	0·90	94·41	..	trace	..	0·88	99·74	0·25	
240	„ ..	„	110	Bottom bed	4·27	0·95	93·52	..	trace	..	0·98	99·72	0·29	
241	Gebel Zawiet Nasra	„	945	Top bed	3·19	1·01	93·03	1·24	1·90	..	trace	100·37	1·24	The soluble matter is largely calcium sulphate.
242	„	„	945	Bottom bed	2·32	0·30	98·05	..	trace	..	trace	100·67	0·35	
247	„	„	94	Top bed	4·53	0·95	92·31	..	trace	..	1·54	99·33	0·66	The soluble matter is largely sodium chloride.
248	„	„	94	Bottom bed	3·25	1·31	94·23	..	trace	..	1·46	100·25	0·38	
249	„	„	77	Top bed	1·76	0·50	94·40	1·83	1·98	..	0·09	100·56	1·44	The soluble matter is largely calcium sulphate.
250	„	„	77	Bottom bed	3·40	1·17	91·23	1·93	1·75	..	1·08	100 56	1 65	The soluble matter is largely calcium sulphate.
251	Gebel Abyad.. ..	„	10	Top bed (dry) ..	2·15	0·92	95·98	..	1·69	..	trace	100·74	0 44	
252	„ ..	„	10	Bottom bed (wet) ..	6·00	1·19	90·44	..	trace	..	1·83	99·46	0·49	
253	„ ..	„	10	Bottom bed (dry) ..	1·84	0·86	92·91	2 77	trace	..	1·41	99·79	1·81	The soluble matter is largely calcium sulphate.
254	„ ..		55	Top bed	2·40	1·19	95·46	..	trace	..	1·25	100·30	0·18	
255	„ ..	„	55	Bottom bed	4·00	0·60	94·17	..	1·29	..	0·58	100·64	0·20	
256	Gebel Madessa ..		35	Top bed	2·54	0·61	94·85	..	2·25	..	trace	100·25	0·85	
257	„ ..	„	35	Bottom bed .. .	5·65	0·38	92·17	..	1·90	..	0·36	100·46	0·48	
258	„ ..	„	429	Top bed	1·35	0·35	97·84	..	1·27	..	0·05	100·86	0·35	
259	„ ..	„	429	Middle bed	2·67	0·45	94·01	2·92	trace	..	trace	100·05	1·54	The soluble matter is largely calcium sulphate.
260	„ ..	„	429	Bottom bed	6·80	1·72	89·89	..	1·71	..	0·82	100·94	0·42	
261	Gebel Doweiqa ..		431	Top bed	0·78	0·28	99·03	..	trace	..	0·05	100·14	0·48	
262	„ ..	„	431	Bottom bed	5·32	0·86	93·16	..	1·10	..	0·30	100·74	0·51	
263	, ..	„	16	Top bed	0·60	0·35	98·74	..	trace	..	0·35	100·04	0·27	
264	„ ..	„	16	Bottom bed	3·77	0·88	93·71	..	trace	..	1·73	100 09	0·64	